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Design of a web-based information system for ambient environmental data

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Abstract

The development of a new web-based information dissemination system in West Macedonia in Greece is described. The system has been developed for online use, giving the concentrations of PM10, PM2.5, SO_2, NO_X, O_3, CO, as well as meteorological data (temperature, humidity, solar radiation, wind speed and direction). The European air quality limits for each measured pollutant are also provided for comparison together with the calculated Air quality index (AQI) that is displayed on a color based scale showing the various categories. Based on the temperature and humidity values the discomfort index is also calculated and is displayed descriptively. For more accurate estimation of the AQI, a surrogate method for estimating AQI is also used to assess air quality conditions at a given time. Four cities are dealt with by the system, the capitals of the prefectures of West Macedonia, with five locations specifically covered. The system of assessing the status of air quality has been developed and designed in a format understandable by the public and managers, and will aid the understanding of the relevant issues. The URL of the website is http://airlab.teikoz.gr.

Keywords: Air quality index; Discomfort index; Environmental web based data processing; Environmental information systems

1. Introduction

The development and application of telematics has led to more automated systems of environmental control. Nowadays, telematics provide new capabilities such as access to databases of distributed spatial information, and the processing of primary data and results at any distance from the rapidly transmitted information. The systems of control should take into account, apart from pollution parameters, various regulations at the national, European or international level. This is an element that makes an automated system be more than a pure system of reception and storage of data. It is also a requirement for 'New Generation' environmental control tools to be flexible, dynamic, responsive and specifically featured for the management and distribution of environmental information. Comprehensive environmental information can be propagated via the internet rapidly, simply, in real-time and with any additional and historical elements to the public (Zhu and Dale, 2000; Schimak, 2003; Sharma et al., 2003).

The objective of this work is the presentation of a web based dynamic ambient air quality data management system for West Macedonia, Greece. This is a new data dissemination approach based on the novel combination of the data processing techniques, software and hardware used for the manipulation of real time environmental information. It has been developed and operated by the Lab of Atmospheric Pollution and Environmental Physics (LAP-EP).

2. Materials and methods

2.1. Description of the web-based information system

The monitoring of air quality is of paramount importance in this region due to the industrial activity and the emitted pollutants involved (Triantafyllou, 2003). In addition, this was the first attempt to establish a web-based information system away from the main Greek cities of Athens and Thessaloniki. The system, with a suitably designed web page, has the ability of giving real time results of measurements of air pollution and meteorological parameters that depict the atmospheric conditions in the capitals of the four prefectures of West

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Macedonia as well as at the Technological Education Institute (TEI) where the central operating equipment is located. The experimental measurements include concentrations of particulate matter with an aerodynamic diameter less than 10 μm (PM10) and 2.5 μm (PM2.5), sulfur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), and carbon monoxide (CO), temperature, relative humidity, solar radiation (total, UVA and UVB only at TEI monitoring station), wind speed and direction. The display refers to tables that give the quality limits of the European Union (EU) for each gas pollutant that is measured. Simultaneously, aiming at enhanced comprehension by the wider public, the information is simplified by the use of air quality and bioclimatic indices. Specifically, from the measured concentrations, the air quality index AQI (EPA, 1997) is calculated and depicted on the display by a suitable chromatic scale. The discomfort or bioclimatic index is determined from the temperature and humidity values (Thom, 1959). In order to assess air quality conditions at a given time using the AQI, one would ideally use the average particle pollution measurement over a 24-h window centered about the hour being measured (i.e. mid point of the 24 h range, Mid-24) to compute the AQI. The issue, however, in protecting public health via the AQI for particles is that 12 h of future data are not available. Therefore, the surrogate method that is used in this study is to combine hourly particulate concentrations from previous hours to estimate the Mid-24 average. Details on surrogate methods and testing according to four criteria can be found elsewhere (McMillan, 2004).

The system was given the code name EAP-1. It covered the capitals of the four prefectures in the area, where measurements were taken during the period June 2002–2004, in a project that was initiated by the Regional Authority of West Macedonia in order to estimate the air quality levels in the greater area. Nowadays, the system operates only for the city of Kozani and the local station at TEI. Past data are available on the web site for the rest of the stations. Note that the system can be applied for any number of network stations.

2.2. Air quality index (AQI)

The AQI constitutes a modification (improvement) of the air pollution index systems PSI (Ott and Thom, 1976; Thom and Ott, 1976; Triantafyllou et al., 2002) and includes an additional intermediate category described as 'unhealthy for sensitive groups' as well as individual indices for PM10 and PM2.5 concentrations (EPA, 1997). Even though there are some important efforts in establishing a European standard method (Kassomenos et al., 1999) it was decided that the EPA's widely used and tested method was the most appropriate to be applied in EAP-1. The values of the AQI determine the air quality according to Table 1.

The values of the individual indices together with the corresponding concentrations of pollutants that form them are shown in Table 2. The AQI is estimated according to the pollution measurements in Table 2 and the following linear interpolation equation:

Table 1
AQI scales of assessment for air quality (EPA, 1997)

AQI values	Levels of health concern	Colors
0–50	Good	Green
51–100	Moderate	Yellow
101–150	Unhealthy for sensitive groups	Orange
151–200	Unhealthy	Red
201–300	Very unhealthy	Purple
300–500	Hazardous	Maroon

$$I_{\mathrm{p}} = \frac{I_{\mathrm{Hi}} - I_{\mathrm{Lo}}}{BP_{Hi}} \,{}^{\mathrm{Hi}}\!BP_{\mathrm{Lo}}(C_{\mathrm{p}} - BP_{\mathrm{Lo}}) + I_{\mathrm{Lo}} \quad (1)$$

where I_p is the index for pollutant p, C_p the concentration of p, BP_{Hi} the breakpoint that is greater than or equal to C_p, BP_{Lo} the breakpoint that is less than or equal to Cp, I_{Hi} the AQI value corresponding to BP_{Hi} and I_{lo} the AQI value corresponding to BP_{Lo}.

2.3. PM surrogate method

The AQI for particulate pollutants can be calculated by a surrogate method (EPA, 2004, http://www.epa.gov/airnow/faq.html) that was developed for assessing air quality conditions over a 24-h period. It is only calculated for particulate pollutants (PM10, PM2.5).

EPA's surrogate method combines both the 4-h average and the 12-h average concentrations in the following manner:

(1) Calculate the average of the previous 12 h.
(2) Calculate the ratio of the most recent hour to the average of the previous 12 h.
(3) Calculate an 'Adjusted' hourly value:
- The adjusted hourly value is equal to the actual hourly value, if the actual hourly value is <30 μg/m^3.
- The adjusted hourly value is equal to the actual hourly value, if the actual hourly value is >30 μg/m^3 and the ratio of the most recent hourly value to the average of the most recent 12 h values is <0.9 or >1.7.
- Otherwise, the adjusted hourly value is equal to 0.75 times the actual hourly value.

(4) Calculate the 'Adjusted' 4-h average, which is the average of the four most recent 'Adjusted' hourly values.
5. Estimate the Mid-24 as:

$$\mathrm{Mid}-24 = \frac{(12 * (12-\mathrm{h\ average}) + 12 * (4-\mathrm{h\ adjusted\ average}))}{24} \quad (2)$$

In summary, the surrogate method uses the average of the 12-h average and an adjusted 4-h average for particles. These estimated concentrations are used until 18 out of 24 values or more are available for calculating a 'real' mid-point 24-h average for each hour of the day. Fig. 1 shows a 1-week

Table 2
AQI categories (EPA, 1997)

Levels of health concern	AQI	O_3 (ppm) 8-h	O_3 (ppm) 1-h[a]	$PM_{2.5}$, 24 h (μg/m^{3})	PM_{10}, 24 h (μg/m^{3})	CO, 8-h (ppm)	SO_2, 24-h (ppm)	NO_2, 1-h (ppm)
Good	0–50	0.000–0.064	–	0.0–15.4	0–54	0.0–4.4	0.000–0.034	([b])
Moderate	51–100	0.065–0.084	–	15.5–40.4	55–154	4.5–9.4	0.035–0.144	([b])
Unhealthy for sensitive groups	101–150	0.085–0.104	0.125–0.164	40.5–65.4	155–254	9.5–12.4	0.145–0.224	([b])
Unhealthy	151–200	0.105–0.124	0.165–0.204	65.5–150.4	255–354	12.5–15.4	0.225–0.304	([b])
Very unhealthy	201–300	0.125–0.374	0.205–0.404	150.5–250.4	355–424	15.5–30.4	0.305–0.604	0.65–1.24
Hazardous	301–500	([c])	0.405–0.604	250.5–500.4	425–604	30.5–50.4	0.605–1.004	1.25–2.04

[a] The AQI for ozone is based on the 8-h average ozone concentration, which is computed by averaging the measured hourly ozone concentrations over an 8-h period. However, in some cases regions where the AQI is based on the hourly ozone concentrations may be more helpful. In these instances apart from the calculation of the 8-h ozone exposure based index the recorded hourly based index would provide the maximum value between them.

[b] Determination of AQI according to NO_2 limits is only allowed for values greater than 200 due to the absence of national standards.

[c] When the 8-h O_3 concentrations exceed the value of 0.374 ppm, then the AQI should be calculated by the hourly concentration.

comparison between the estimated Mid-24 and the real Avg-24. The employed surrogate method seems to perform well for the AQI assessment at a given time with 87% agreement. This is better than McMillan's (2004) criterion where the surrogate method should be within 70–80% of Mid-24 after a multi method comparison for four cities.

2.4. Discomfort index

The discomfort index (DI) being used is a bioclimatic index that describes the degree of human discomfort due to hot and humid conditions (Thom, 1959). It is given by the following relation:

$$DI = T_a - 0.55(1 - 0.01\ \mathrm{RH})(T_a - 14.5) \quad (3)$$

where T_α is the mean hourly air temperature (°C) and RH the respective relative humidity (%). The DI evaluation ranges between the limits shown in Table 3.

2.5. The development and implementation of EAP-1

The complete flow diagram of the wed based information system is described in Fig. 2. The five monitoring stations were equipped with sampling instrumentation for the measurement of SO_2, NO_x, CO, O_3, PM10, PM2.5, as well as meteorological parameters of temperature, humidity, wind speed and direction. The central station at TEI also measures atmospheric pressure, total solar radiation, UVA and UVB. Specially developed software stores all experimental data locally at every station before it is downloaded from the primary web server at LAP-EP via modem or leased line or GPRS.

There has also been a camera facility in each station-for situation assessment purposes (e.g. traffic)-which has the ability of connecting directly to the local network or via modem to the Internet Service Provider (ISP) and via FTP sends video or photographs in the central web server.

The central server is responsible for the collection, processing and storage of data from all the stations via a commercial program ('commserv'). The data storage and processing is done by the SQL server and through a control-filter that rejects faulty measurements due to a variety of reasons (calibration, troubleshooting diagnostics of the analyzers, etc.) using code written in visual script (Fig. 3).

The manipulated data are sent to the web page after the execution of a code written in T-SQL, which produces an ASCII formatted file with the most recently saved information from each station. Consecutively, a program written in visual basic is executed (Fig. 4 flow diagram) that reads the experimental data and displays on the screen the calculated AQI in a colored scale and DI values together with the pollutants' concentrations for every location. For comparison

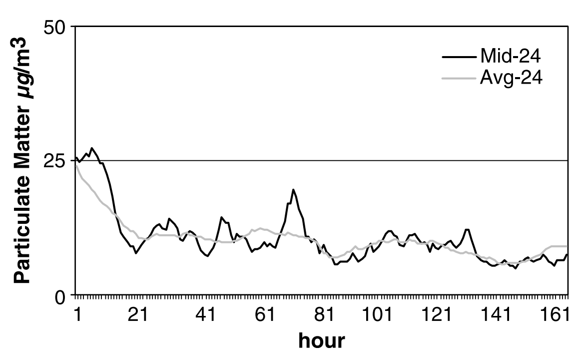

Fig. 1. Comparison between Mid-24 and Avg-24 values for a week.

Table 3
Discomfort index categorization (Giles et al., 1990)

DI	Discomfort categories
DI<21	None uncomfortable
21=<DI<24	Some people <50% uncomfortable
24=<DI<27	Many people >50% uncomfortable
27=<DI<29	Most people uncomfortable
29=<DI<32	Anyone uncomfortable
DI>=32	Danger of exhaustion/stroke

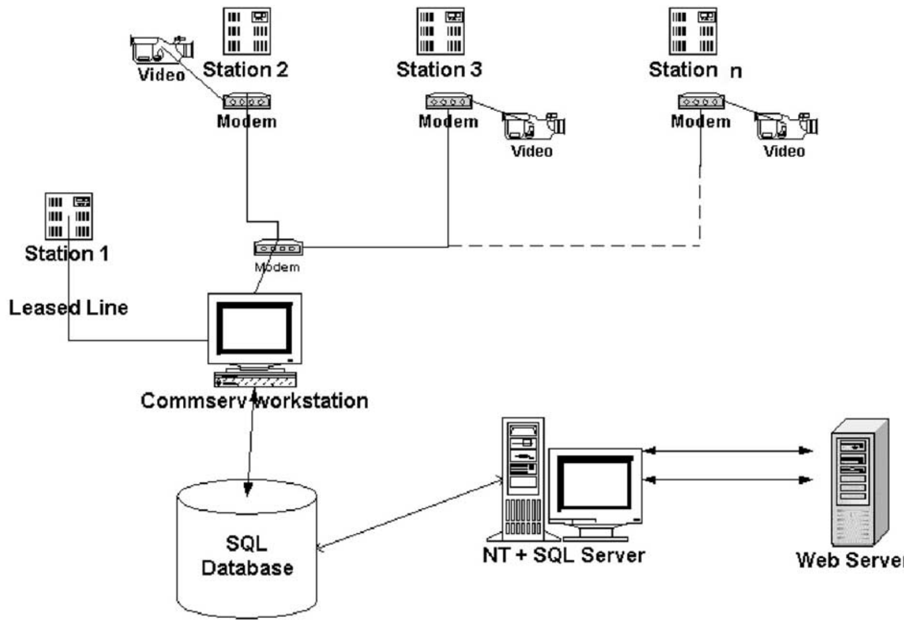

Fig. 2. System flow diagram.

the AQI and DI values of the previous day are also available on the screen. Web page refreshing can be applied every 5 min-this also updates to the most recent picture sent by the camera.

The user is provided with a clickable map of the region for the selection of a particular city (Fig. 5). For each station a new HTML file is produced which shows the city and station names together with the measurements and processed results (Fig. 6). A comparison between HTML pages relating to different stations can be carried out by the use of the window minimization tool.

3. Results and discussion

3.1. Web site number of visits

Access to the URL of the designed web site http://airlab.teikoz.gr has been free since July of 2003. From August 2004 to July 2005 the total URL visits reached a number on the order of 16500 while the average number of daily visits during this period was about 236. This has increased with time and reached an average of more than 800 visits daily in July of 2005.

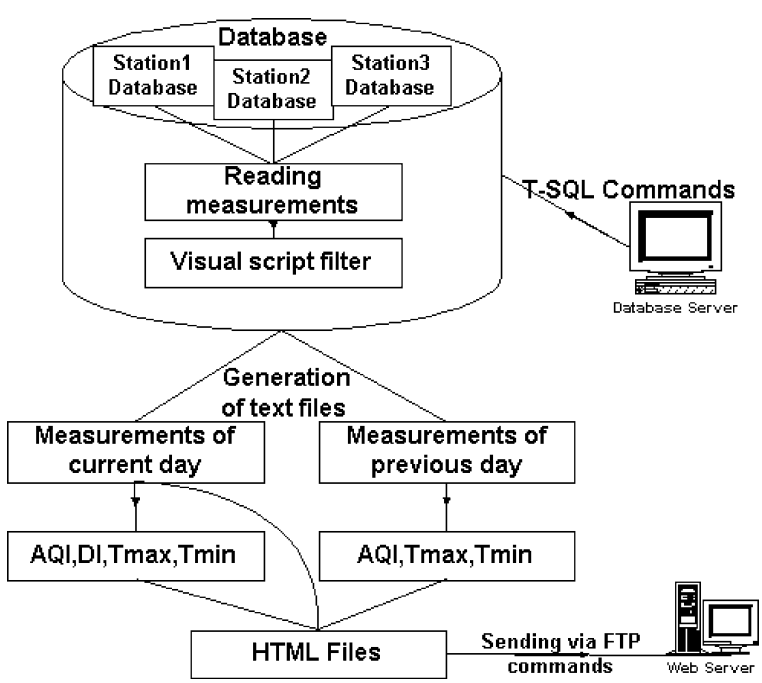

Fig. 3. SQL commands description for data storage and filtering.

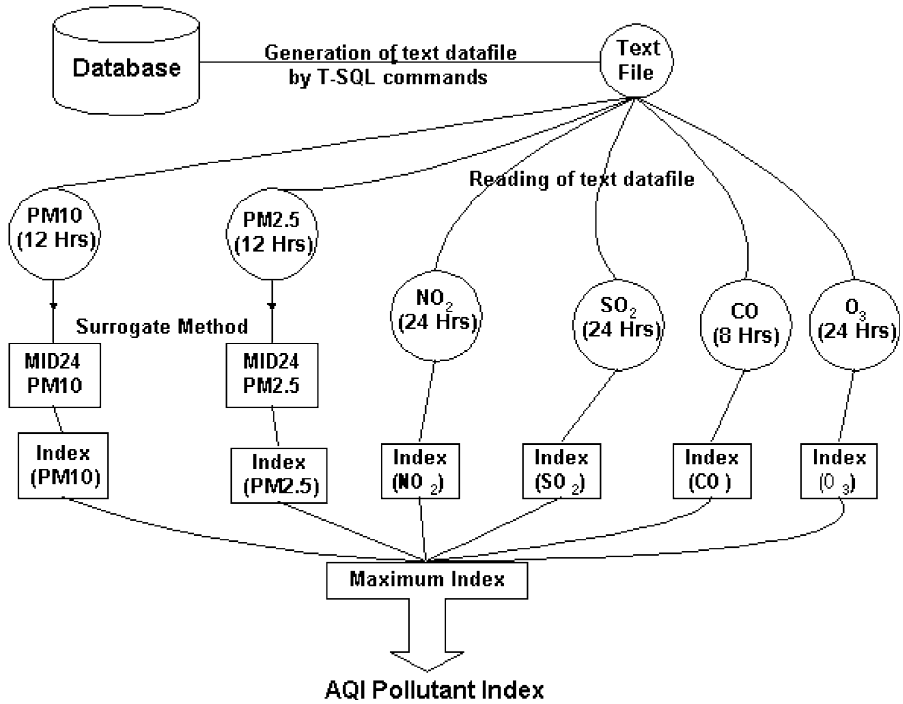

Fig. 4. Visual basic program flow diagram for the calculation of AQI.

3.2. Description of the users and feedback

The web site has been acknowledged by a national newspaper as a prototype and interesting source in the sector of environmental management. It is also linked with other local servers mainly used by the public. Local authorities that deal with the civilians' queries are in collaboration with the development team in order to improve and assess the environmental information provided to the public. Scientists and managers make use of the information provided by the web page for example in regional atmospheric pollution projects. Students have also used the real time information system, from

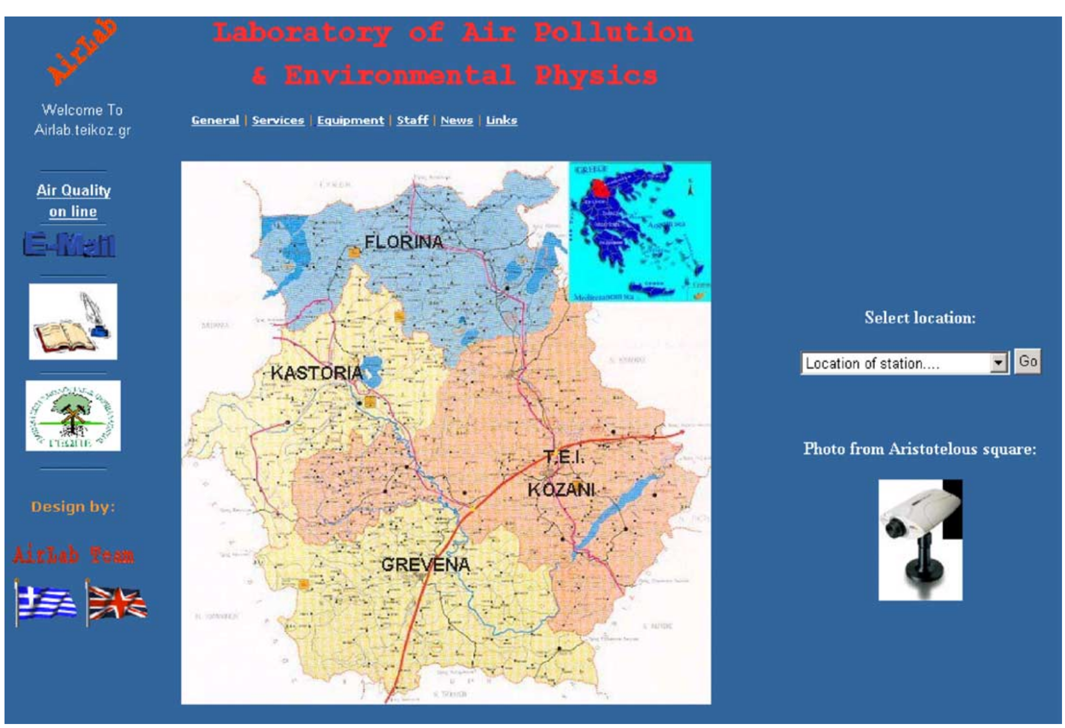

Fig. 5. Homepage of the web site with the five geographical station locations.

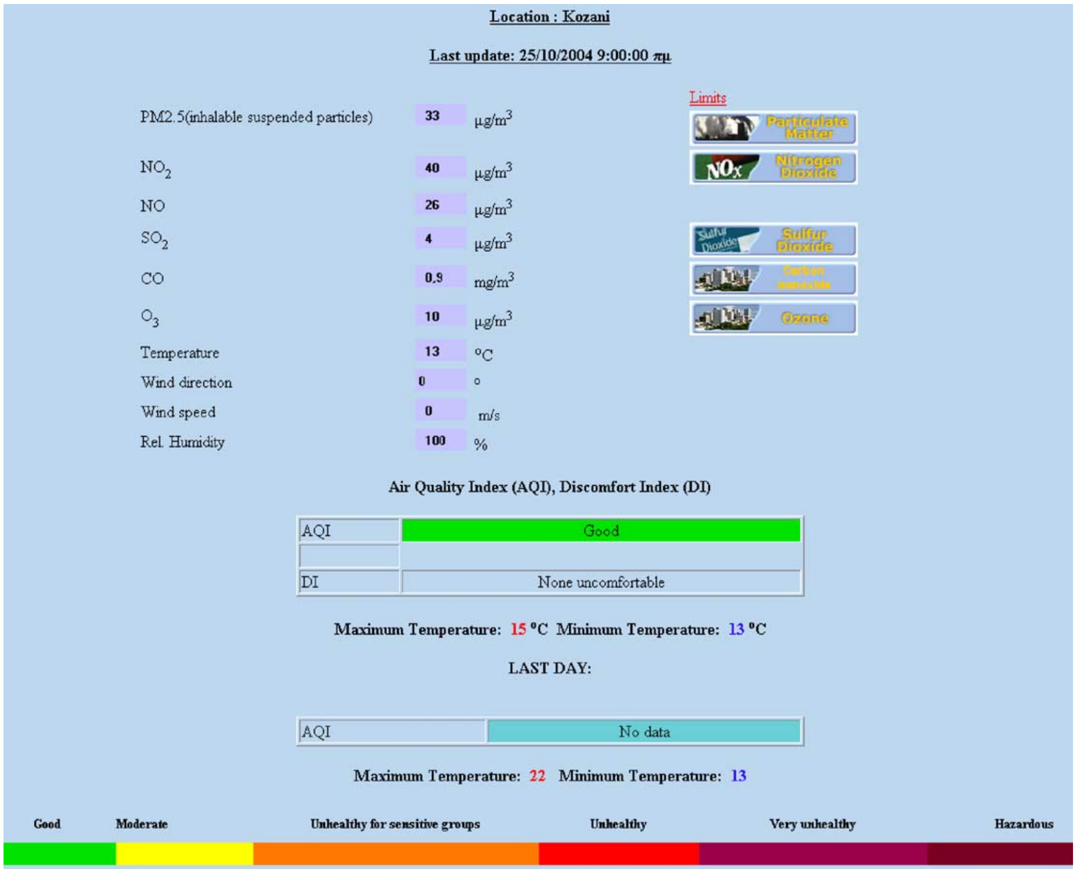

Fig. 6. The HTML file after the selection of 'Kozani' icon (Fig. 3). It shows the data measurements of the city of Kozani on 25th of October in 2004, and below that the colored AQI with the chromatic scale and the DI value. The tabs on the right of the page lead to information about the standards and limits.

all over Greece, in carrying out assignments and dissertations with real experimental data (surface meteorology and pollutants). These included data analysis and air quality assessment, air pollution modeling and GIS applications. Feedback from the users has shown that the current environmental information system would be even more useful if it were accompanied by more options, e.g. prediction and data analysis tools. These are underway in the framework of a restructuring project.

4. Conclusions

A new web-based dynamic ambient air quality data management system (EAP-1) designed for West Macedonia, Greece was presented in this paper. It is a remote air quality data acquisition and monitoring system for real time data collection from a network of stations, data analysis and data presentation. The system supplies the local community with a better awareness of air quality around the area in a simple and comprehensible way by using environmental indices. The AQI and DI are calculated and provided together with the previous day's values for comparison. For more accurate calculation of the AQI, a surrogate method is applied. At a given time the AQI is assessed by the estimation of the Mid-24 particulate matter concentration which is in good agreement with the real Avg-24. The present web based system is designed with no restrictions regarding the area and the number of monitoring stations that can be included in the network. Future improvement of the system is underway by extending its abilities, i.e. the background concentrations, calculation of relative bioclimatic index, next day expected situation and advice for the protection of the public.

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